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SHORT COMMUNICATION

Morphological patterns in the plumular leaf of Japanese *Arisaema* (Araceae)

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The morphology of the plumular leaf was investigated for the 36 taxa (31 species and 5 subspecies) of *Arisaema* (Araceae) in Japan. Of the total, 22 taxa (18 species and 4 subspecies) were newly observed. Four morphological plumule patterns, i.e. without blade, with a simple and cordate blade, with a simple and hastate blade, and with a trifoliolate blade, were recognized. The patterns are considered in relation to the taxonomic treatment of Japanese *Arisaema*.

Key words: *Arisaema*, plumular leaf, seedling, taxonomy

Hotta (1964) examined seedlings of twenty Japanese and Himalayan species of *Arisaema* (Araceae) and attempted to correlate the morphological pattern of plumular leaves with the phylogeny of the genus. Murata (1984, 1986a) (referring to the first leaf following the cotyledon) and Gusman & Gusman (2002, 2006) (citing the eophyll) added further information about this character. As a result, the morphological pattern of the plumular leaves of 28 Japanese taxa (27 species and 1 subspecies) and 56 taxa outside Japan was described. Five patterns (character states) were recognized for the Japanese species; 1) blade simple, cordate 2) blade simple, hastate, 3) blade trifoliolate, 4) blade 5-foliolate, 5) without blade. Using this character, Gusman & Gusman (2006) proposed a subsectional classification of *Arisaema* section *Pistillata* (Engler) Nakai. The morphology of the plumular leaf, however, was still unknown for more than half of the 60 taxa (51 species and 9 subspecies) indigenous to Japan (Murata 2011).

The aim of our study was to add information about previously unexamined or erroneously observed species and to comment on the morphological pattern of plumular leaves in relation to the taxonomy of *Arisaema* in Japan and to reevaluate the subsectional classification of Gusman & Gusman (2006).

Materials and methods

We collected seeds from plants growing in the wild. Plants with immature fruit were transplanted to the first author's garden for later harvesting. Mature seeds were sown in flower pots and germinated in the spring. The seedlings were photographed and made into voucher specimens. During the flowering season, voucher specimens of the mother plants with an inflorescence were also collected. Voucher specimens are deposited in the herbaria of the Museum of Nature and Human Activities, Hyogo (HYO) and the University of Tokyo (TI).

Results

The plumular leaves of 49 taxa are shown in Table 1. Photos of living or dried seedlings of the 36 taxa observed in this study are shown in Figs.

1 to 3. No new patterns were found.

The plumular leaves of 22 of the 36 taxa observed in this study are reported for the first time. The blade of the plumular leaf is simple and cordate (heart-shaped) in 6 taxa, simple and hastate (shallowly trisected) in 4 taxa and trifoliolate in 12 taxa. The report for *A. kawashimae* was based on field observations by Mr. Yamashita in Kagoshima Prefecture, but one of us (Kobayashi) also observed a leaf, presumed to be plumular, with a trifoliolate blade in the field (Fig. 2M).

The observations of the 12 taxa agreed with previous reports. The blade of the plumular leaf of *A. limbatum* and *A. kiushianum*, described as simple by Gusman & Gusman (2002), was determined to be cordate, with which Dr. G. Gusman concurred (pers. comm.).

Two other reports, however, do not agree with our findings and are considered to be incorrect. Although Gusman & Gusman (2006) regarded the blade of the plumular leaf of *A. cucullatum* as trifoliolate, it was found to be cordate in this work. We also found the plumular leaf of *A. kiushianum* to have a simple, cordate blade, even though Hotta (1964, pers. comm.) reported it to be a bladeless sheath.

TABLE 1. Pattern of the plumular leaves for the 49 taxa (42 species and 7 subspecies) in Japanese *Arisaema* in comparison with the sections, subsections and unranked infrageneric groups.

Taxa (Figure of the seedlings)	Pattern of plumular leaves				Section*	Subsection**	Unranked group
	Present study		Previous reports				
		Voucher specimen of the mother plants and [seedlings]. (n=) number of mother plant examined		Literature			
A. ringens Schott (Fig. 1G)	Sc	*Kobayashi 40576*, [*40905*] (n = 2)	Sc	Hotta (1964), Murata (1984), Gusman & Gusman (2002)	PI	R	
A. ternatipartitum Makino (Fig. 1I)		*Kobayashi 36878* (n = 1)	Sc	Hotta (1964), Murata (1984), Gusman and Gusman (2002)		PI	
A. cucullatum M. Hotta (Fig. 1B)		*Kobayashi 42316*, [*43344*] (n = 2)	T****	Gusman & Gusman (2006)		PE	
A. seppikoense Kitam. (Fig. 1H)		*Kobayashi 43925* (n = 2)					
A. aequinoctiale Nakai & F. Maek. (Fig. 1A)		*Kobayashi 42977, 43975*, [43934] (n = 2)				PI	*undulatifolium* (Kobayashi *et al.* 2003)
A. limbatum Nakai & F. Maek. (Fig. 1D)		*Kobayashi 35745*, [*43932*] (n = 1)	S	Gusman & Gusman (2002)			
A. minus (Seriz.) J. Murata (Fig. 1E)		*Kobayashi 30245, 39932* (n = 3)					
A. nambae Kitam. (Fig. 1F)		*Kobayashi 42982, 42969*, [*43935*], [*43936*] (n = 5)					
A. undulatifolium Nakai ssp. *undulatifolium* (Fig. 1K)		*Kobayashi 42445* (n = 2)					
A. undulatifolium ssp. *uwajimense* T. Kobayashi & J. Murata (Fig. 1J)		*Kobayashi 38018* (n = 1)					
A. aprile J. Murata (Fig. 2I)	T	*Kobayashi 47594*, [*48020*] (n = 1)					*nikoense* (Kobayashi *et al.* 2010, Serizawa 1981a, 1986)
A. ishizuchiense Murata			T**** Sh	Hotta(1964) Murata(1984), Gusman & Gusman (2002)			
A. nikoense ssp. *alpicola* (Seriz.) J. Murata (Fig. 2E)	Sh	*Kobayashi 41566*, [*42349*] (n = 2)					
A. nikoense ssp. australe (M. Hotta) Seriz. (Fig. 2C)		*Kobayashi 41907*, [*42353*] (n = 2)					
A. nikoense ssp. nikoense (Fig. 2D)		*Kobayashi 41534*, *42348* (n = 2)	Sh	Murata(1984), Gusman & Gusman (2002)			
A. ogatae Koidz. (Fig. 2F)		*Kobayashi 44757*, [*45630*] (n = 1)					
A. nagiense T. Kobayashi, K. Sasamura & J. Murata (Fig. 2A, B)	Nb (Sh)	*Kobayashi 44819* (n = 1)					*ovale* (Kobayashi *et al.* 2008)
A. ovale Nakai			Sh	Murata (1984)			

Table 1. Continued.

A. longipedunculatum M. Hotta			Sh	Hotta (1964), Murata (1984), Gusman & Gusman (2002)	PI	PI	
A. sachalinense (Miyabe & Kudo) J. Murata			S	Gusman & Gusman (2002)			
A. angustatum Franch. & Sav. (Fig. 2H)	T	*Kobayashi 39370* (n = 1)	T	Hotta (1964)		PE	
A. ehimense J. Murata & J. Ohno (Fig. 2J)		*Kobayashi* [*42350*] (n = 1)					
A. hatizyoense Nakai (Fig. 2K)		*Ohno s.n., Kobayashi* [*40908*] (n = 1)					
A. iyoanum Makino ssp. *iyoanum* (Fig. 2L)		*Kobayashi 40829* (n = 2)	T	Hotta (1964), Murata (1984), Gusman & Gusman (2002)			
A. iyoanum Makino ssp. *nakaianum* (Ohba) H. Ohashi & J. Murata		*Kobayashi 37115* (n = 1)					
A. japonicum Blume			T	Hotta (1964)			
A. kawashimae Seriz. (Fig. 2M)	T	*Kobayashi 42833* (n = 1)***					
A. kishidae Makino (Fig. 3A)		*Kobayashi 40676,41564*, [*42345*] (n = 2)	T	Hotta (1964), Murata (1984), Gusman & Gusman (2002)			
A. kuratae Seriz. (Fig. 3B)		*Kobayashi 42315*, [*42352*] (n = 5)	T	Gusman & Gusman (2006)			
A. maekawae J. Murata & S. Kakishima		*Ohno s.n.* (n = 1)					
A. monophyllum Nakai			T	Murata (1984), Gusman & Gusman (2002)			
A. maximowiczii (Engl.) Nakai	T	*Kobayashi 43181* (n = 1)					
A. peninsulae Nakai ssp. *peninsulae* (Fig. 3C)			T	Hotta (1964)			
A. peninsulae Nakai ssp. "masadanum"	T	*Kobayashi 42317*, [*42344*] (n = 1)					
A. sazensoo (Blume) Makino (Fig. 3D)		*Ohno s.n.* (n = 1)	T	Murata (1984), Gusma & Gusman (2002)			
A. sikokianum Franch. & Sav.			T	Hotta (1964), Gusman & Gusman (2002)			
A. serratum (Thunb.) Schott (Fig. 3E)	T	*Kobayashi* [*42394*] (n = 1)	T	Hotta (1964)			
A. takedae Makino (Fig. 3F)		*Kobayashi 39366*, [*40906*] (n = 5)					
A. tashiroi Kitam. (Fig. 3G)		*Kobayashi 46995* (n = 2)					
A. tosaense Makino			T	Hotta (1964), Murata (1984), Gusman & Gusman (2002)			
A. abei Seriz. (Fig. 2G)	T	*Kobayashi 45814, 45815* (n = 5)					*yamatense* (Serizawa 1980b)
A. yamatense Nakai ssp. *sugimotoi* (Nakai) H. Ohashi & J. Murata (Fig. 3H)		*Kobayashi 42392*, [*42395*] (n = 2)					
A. yamatense (Nakai) Nakai ssp. *yamatense* (Fig. 3I)		*Kobayashi 30294*, [*42393*] (n = 1)	T	Gusman & Gusman (2002)			
A. heterocephalum Koidz. ssp. *majus* (Seriz.) J. Murata			F	Murata (1986)	CL		
A. negishii Makino			Nb	Murata (1984)			
A. heterophyllum Blume	T	*Kobayashi 33054*, [*43346*] (n = 1)	T	Murata (1984), Gusman & Gusman (2002)	FL		
A. kiushianum Makino (Fig. 1C)	Sc	*Kobayashi* [*40917*] (n = 1)	S Nb	Gusman(2002) Hotta(1964)			
A. thunbergii Blume ssp. *thunbergii*			Nb	Hotta (1964)			
A. thunbergii Blume ssp. *urashima* (H. Hara) H. Ohashi & J. Murata			Nb	Hotta (1964), Murata (1984), Gusman & Gusman (2002)			

Pattern of the plumular leaf Sc: with a simple and cordate (heart-shaped) blade, Sh: a simple and hastate (shallowly trisected) blade, T: a trifoliolate blade, F: a five-foliolate blade, Nb: without a blade S: with a simple blade (without further information)
Abbreviation of the section and the subsection: PI=*Pistillata*, CL=*Clavata*, FL=*Flagellarisaema*, PE=*Pedatisecta*, R=*Ringentia*
* based on Murata (2011), ** based on Gusman & Gusman (2006), *** personal comminucation from Mr.Yamashita (Kagoshima Pref.), **** doubtful.

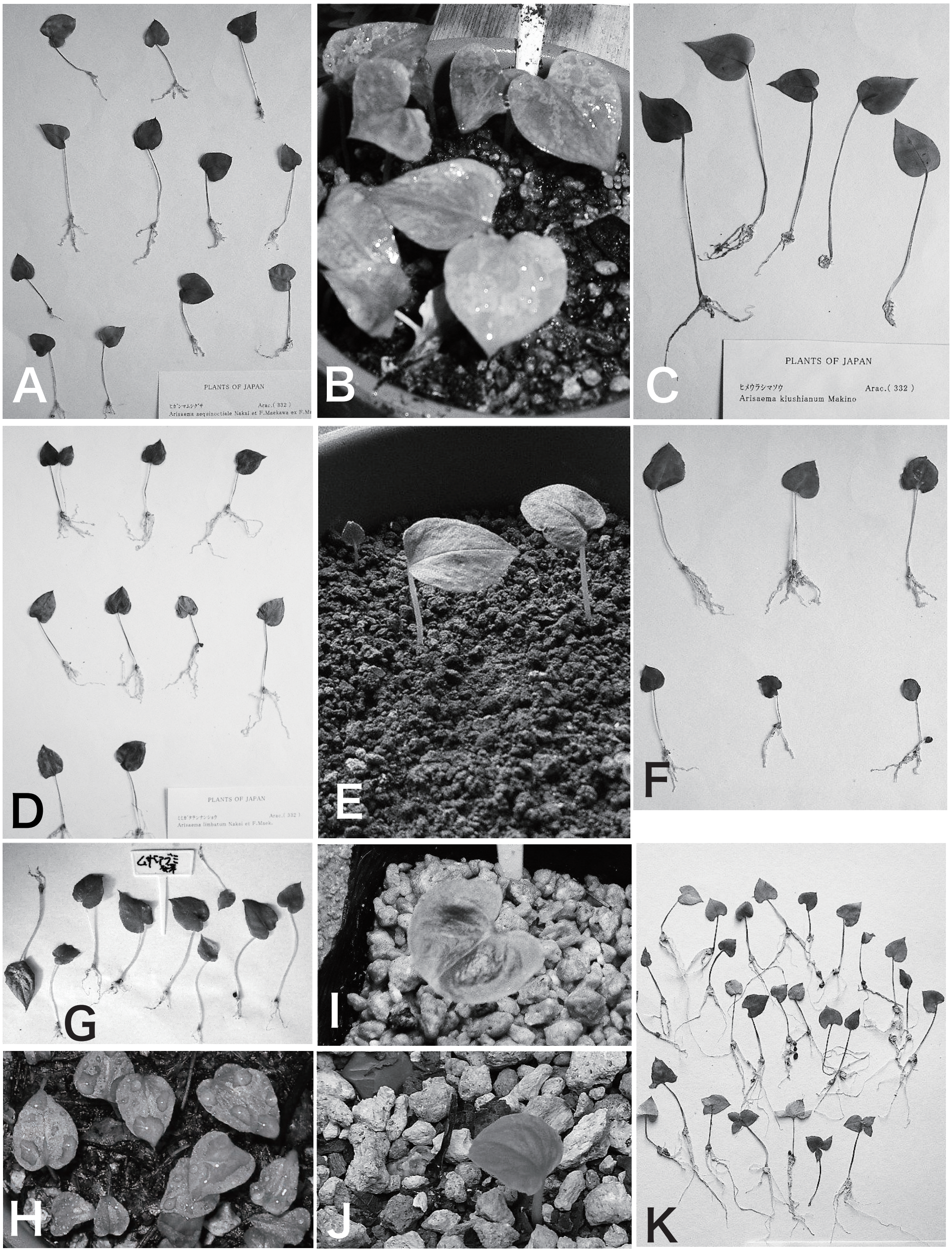

FIG. 1. Plumular leaves of *Arisaema* (1). A. *A. aequinoctiale*. B. *A. cucullatum*. C. *A. kiushianum*. D. *A. limbatum*. E. *A. minus*. F. *A. nambae*. G. *A. ringens*. H. *A. seppikoense*. I. *A. ternatipartitum*. J. *A. undulatifolium* subsp. *uwajimense*. K. *A. undulatifolium* subsp. *undulatifolium*.

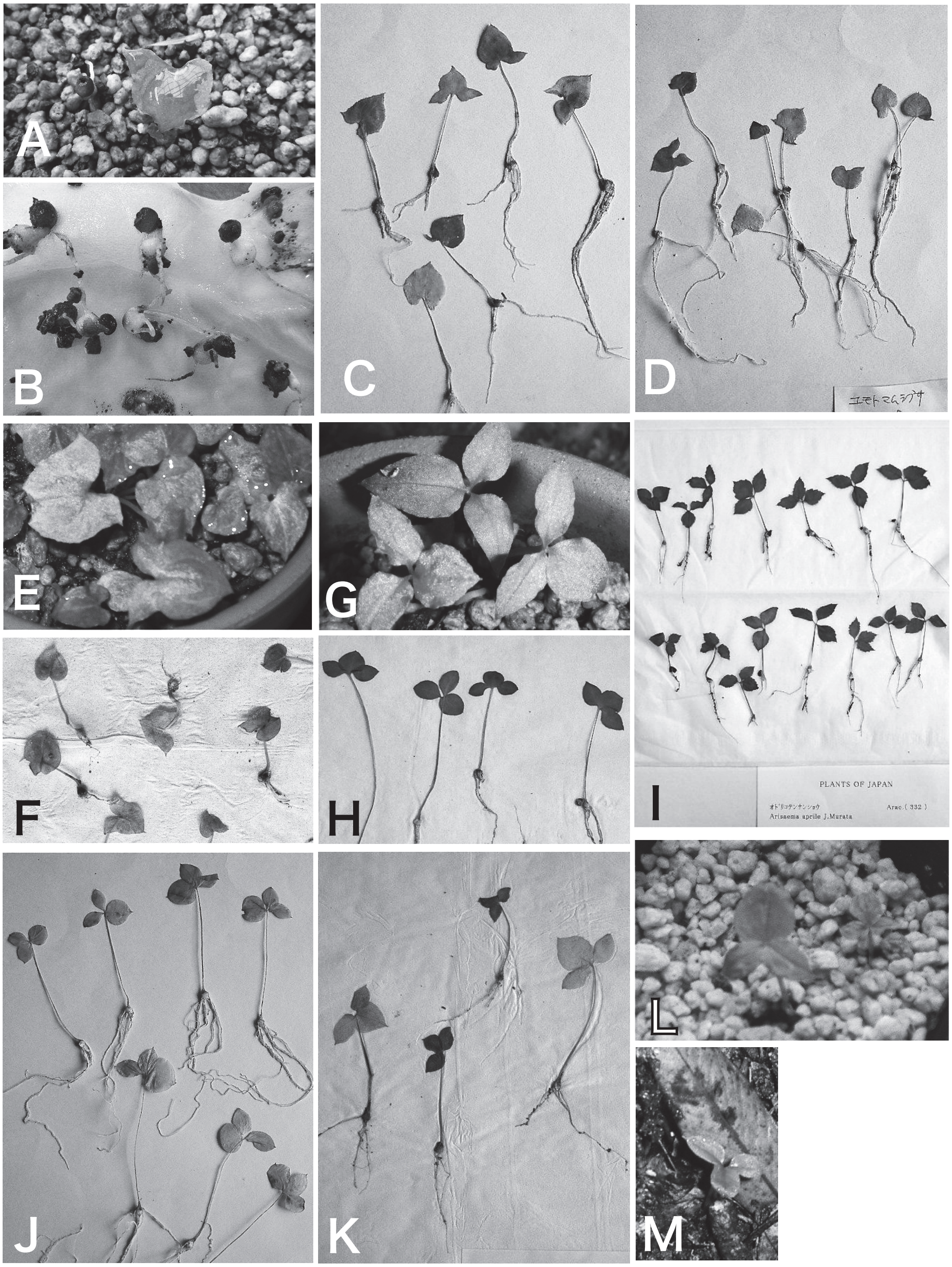

FIG. 2. Plumular leaves of *Arisaema* (2). A, B. *A. nagiense*. C. *A. nikoense* subsp. *australe*. D. *A. nikoense* subsp. *nikoense*. E. *A. nikoense* subsp. *alpicola*. F. *A. ogatae*. G. *A. abei*. H. *A. angustatum*. I. *A. aprile*. J. *A. ehimense*. K. *A. hatijyoense*. L. *A. iyoanum*. M. *A. kawashimae*.

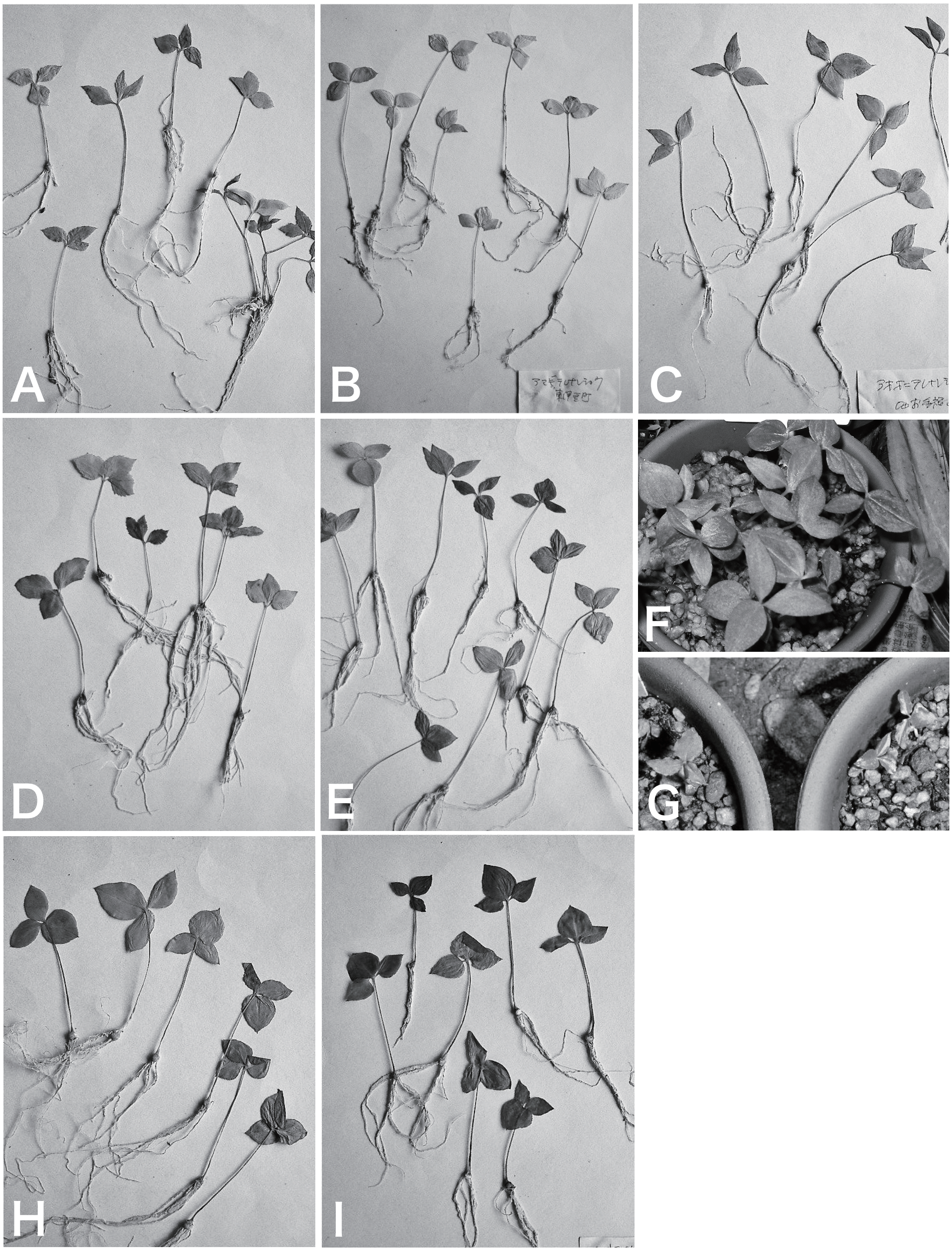

FIG. 3. Plumular leaves of *Arisaema* (3). A. *A. kishidae*. B. *A. kuratae*. C. *A. peninsulae*. D. *A. sazensoo*. E. *A. serratum*. F. *A. takedae*. G. *A. tashiroi*. H. *A. yamatense* subsp. *sugimotoi*. I. *A. yamatense* subsp. *yamatense*.

Discussion

Gusman & Gusman (2006) divided *Arisaema* sect. *Pistillata* into three subsections *Pistillata*, *Pedatisecta* and *Ringetia*, based on the morphology of the plumular leaf. The monotypic subsections *Ringetia* and *Pistillata* were characterized by a plumular leaf with a simple blade, whereas subsect. *Pedatisecta* was characterized by a plumular leaf with a trifoliolate blade. Although Gusman & Gusman (2006) included *A. aprile* in subsect. *Pistillata* and *A. seppikoense* in subsect. *Pedatisecta*, he did not mention the morphology of their plumular leaf. We found that *A. aprile* has a trifoliolate blade and *A. seppikoense* has a simple blade, which does not agree with the systematic positioning of these two species proposed by Gusman & Gusman's (2006).

It is interesting that plumular leaves have a cordate blade in the six taxa of the *A. undulatifolium* group. This group was recognized by Serizawa (1980a) and revised by Murata (1986b) and Kobayashi *et al*. (2003). It is characterized by the association of the highest number of ovules per ovary (more than 10, on average: Murata 1986b, Kobayashi *et al*. 2003, Murata 2011), the spathe opening before extension of the leaves (Serizawa 1980a, Kobayashi 1995) and a chromosome number $2n = 26$, except for *A. nambae*, which has $2n = 28$ chromosomes (Watanabe *et al*. 1998). The cordate plumular leaf may be another characteristic of this group, although it is found in four additional species (*A. ringens, A. ternatipartitum, A. seppikoense* and *A. cucullatum*) in section *Pistillata*.

Plumular leaves with a cordate blade are usually found in species, such as *A. ringens* and *A. ternatipartitum*, that produce trifoliolate adult leaves (Murata 1984). It is therefore remarkable that plumular leaves with a cordate blade occur in both *A. cucullatum* and *A. seppikoense*, as well as in the *A. undulatifolium* group, which has distinctly pedate adult leaves, usually with more than seven leaflets. It is notable that *A. seppikoense* shares the chromosome number $2n = 26$ with members of the *A. undulatifolium* group. The relationship of these species awaits further investigation.

The gross morphology of *A. kawashimae* is similar to *A. undulatifolium*. It was also included in the *A. undulatifolium* group by Serizawa (1980a), but excluded from the group by Kobayashi *et al.* (2003) based on the nature of the spathe that opens after extension of the leaves and the different chromosome number of $2n = 28$. The plumular leaf of *A. kawashimae* was found to be trifoliolate and therefore different in the plumule from the *A. undulatifolium* group.

The plumular leaf of the four core taxa of the *A. nikoense* group (Serizawa 1981a, Serizawa 1986), i.e. *A. ishizuchiense, A. nikoense* subsp. *alpicola, A. nikoense* subsp. *australe, A. nikoense* subsp. *nikoense,* is commonly hastate. The *Arisaema nikoense* group has generally been characterized by the association of short pseudostem, five leaflets, short rachis between the leaflets and a spathe that opens before extension of the leaves, but the circumscription of the group has been unclear. *Arisaema kuratae, A. aprile* and *A. ogatae,* which share most of the characteristics of this group, have sometimes been included in this group. We found that the plumular leaves had a hastate blade in *A. ogatae,* but a trifoliolate blade in *A. kuratae* and *A. aprile.*

The *Arisaema ovale* group is well established and is characterized by spathe tube with raised longitudinal stripes. The chromosome numbers are multiples of 13 (Serizawa 1981b, Murata 1986c, Kobayashi *et al.* 2008) and accessory buds are produced in the polyploids. The plumular leaf of *A. nagiense,* reported here for the first time, basically lacks a blade (Fig. 2B). This feature was found previously only in *A. thunbergii* and *A. negishii* and never in sect. *Pistillata*. Only a single individual out of 26 germinated of *A. nagiense* had a hastate blade (Fig. 2A) as in other species of the *A. ovale* group.

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